

In the Claims:

A. Kindly cancel Claims 5 and 15, without prejudice.

B. Kindly amend Claims 1, 6, 11, and 16, as follows.

1. **(currently amended)** A method of fabricating a semiconductor device, having a reduced-oxygen copper-zinc (Cu-Zn) alloy filled dual-inlaid interconnect structure formed on a copper (Cu) surface formed by electroplating the Cu surface in a chemical solution, comprising the steps of:

5 providing a semiconductor substrate having a Cu surface formed in a via;

providing a chemical solution;

electroplating the Cu surface in the chemical solution thereby forming said a Cu-Zn alloy

fill in the via and on the Cu surface,

wherein said electroplating comprises using an electroplating apparatus,

10 wherein said electroplating apparatus comprises:

(a) a cathode-wafer;

(b) an anode;

(c) electroplating vessel; and

(d) a voltage source, and

15 wherein the cathode-wafer comprises the Cu surface,

rinsing the Cu-Zn alloy fill in a solvent;

drying the Cu-Zn alloy fill under a gaseous flow;

annealing the Cu-Zn alloy fill formed in the via and on the Cu surface, thereby forming

a reduced-oxygen Cu-Zn alloy fill having a uniform zinc distribution;

20 planarizing the reduced-oxygen Cu-Zn alloy fill and the Cu surface, thereby completing

formation of a reduced-oxygen Cu-Zn alloy filled dual-inlaid interconnect

structure; and

completing formation of the semiconductor device.

2. **(original)** A method, as recited in Claim 1,

wherein the chemical solution is nontoxic and aqueous, and

wherein the chemical solution comprises:

at least one zinc (Zn) ion source for providing a plurality of Zn ions;
 at least one copper (Cu) ion source for providing a plurality of Cu ions;
 at least one complexing agent for complexing the plurality of Cu ions;
 at least one pH adjuster;
 at least one wetting agent for stabilizing the chemical solution, all being dissolved
 in a volume of deionized (DI) water.

3. **(original)** A method, as recited in Claim 2,

wherein the at least one zinc (Zn) ion source comprises at least one zinc salt selected
 from a group consisting essentially of zinc acetate $((\text{CH}_3\text{CO}_2)_2\text{Zn})$, zinc bromide
 (ZnBr_2) , zinc carbonate hydroxide $(\text{ZnCO}_3 \cdot 2\text{Zn}(\text{OH})_2)$, zinc dichloride (ZnCl_2) ,
 zinc citrate $((\text{O}_2\text{CCH}_2\text{C}(\text{OH})(\text{CO}_2)\text{CH}_2\text{CO}_2)_2\text{Zn}_3)$, zinc iodide (ZnI_2) , zinc L-
 lactate $((\text{CH}_3\text{CH}(\text{OH})\text{CO}_2)_2\text{Zn})$, zinc nitrate $(\text{Zn}(\text{NO}_3)_2)$, zinc stearate
 $((\text{CH}_3(\text{CH}_2)_{16}\text{CO}_2)_2\text{Zn})$, zinc sulfate (ZnSO_4) , zinc sulfide (ZnS) , zinc sulfite
 (ZnSO_3) , and their hydrates.

4. **(original)** A method, as recited in Claim 2,

wherein the at least one copper (Cu) ion source comprises at least one copper salt
 selected from a group consisting essentially of copper(I) acetate $(\text{CH}_3\text{CO}_2\text{Cu})$,
 copper(II) acetate $((\text{CH}_3\text{CO}_2)_2\text{Cu})$, copper(I) bromide (CuBr) , copper(II) bromide
 (CuBr_2) , copper(II) hydroxide $(\text{Cu}(\text{OH})_2)$, copper(II) hydroxide phosphate
 $(\text{Cu}_2(\text{OH})\text{PO}_4)$, copper(I) iodide (CuI) , copper(II) nitrate $((\text{CuNO}_3)_2)$, copper(II)
 sulfate (CuSO_4) , copper(I) sulfide (Cu_2S) , copper(II) sulfide (CuS) , copper(II)
 tartrate $((\text{CH}(\text{OH})\text{CO}_2)_2\text{Cu})$, and their hydrates.

5. **(canceled)**

6. **(currently amended)** A method, as recited in Claim 51,

~~wherein the cathode-wafer comprises the Cu surface, and~~

wherein the anode comprises at least one material selected from a group consisting
 essentially of copper (Cu), a copper-platinum alloy (Cu-Pt), titanium (Ti),
 platinum (Pt), a titanium-platinum alloy (Ti-Pt), an anodized copper-zinc alloy

(Cu-Zn, i.e., brass), a platinized titanium (Pt/Ti), and a platinized copper-zinc (Pt/Cu-Zn, i.e., platinized brass).

7. **(original)** A method, as recited in Claim 1,
wherein said semiconductor substrate further comprises a barrier layer formed in the via
under said Cu surface, and
wherein the barrier layer comprises at least one material selected from a group consisting
essentially of titanium silicon nitride ($\text{Ti}_x\text{Si}_y\text{N}_z$), tantalum nitride (TaN), and
tungsten nitride (W_xN_y).
8. **(original)** A method, as recited in Claim 7,
wherein said semiconductor substrate further comprises an underlayer formed on the
barrier layer,
wherein said underlayer comprises at least one material selected from a group consisting
essentially of tin (Sn) and palladium (Pd), and
wherein said Cu surface is formed over said barrier layer and on said underlayer.
9. **(original)** A method, as recited in Claim 8,
wherein said underlayer comprises a thickness range of approximately 15 Å to
approximately 50 Å,
wherein said barrier layer comprises a thickness range of approximately 30 Å to
approximately 50 Å,
wherein said Cu surface comprises a thickness range of approximately 50 Å to
approximately 70 Å, and
wherein said Cu-Zn alloy fill comprises a thickness range of approximately 300 Å to
approximately 700 Å.
10. **(original)** A method, as recited in Claim 1,
wherein the annealing steps are performed in a temperature range of approximately
150°C to approximately 450°C, and
wherein the annealing steps are performed for a duration range of approximately 0.5
minutes to approximately 60 minutes.

11. **(currently amended)** A semiconductor device, having a reduced-oxygen copper-zinc (Cu-Zn) alloy filled dual-inlaid interconnect structure formed on a copper (Cu) surface formed by electroplating the Cu surface in a chemical solution, fabricated by a method comprising the steps of:

5 providing a semiconductor substrate having a Cu surface formed in a via;
providing a chemical solution;

electroplating the Cu surface in the chemical solution, thereby forming a Cu-Zn alloy fill in the via and on the Cu surface;

wherein said electroplating comprises using an electroplating apparatus,

10 wherein said electroplating apparatus comprises:

(a) a cathode-wafer;

(b) an anode;

(c) electroplating vessel; and

(d) a voltage source, and

15 wherein said cathode-wafer comprises the Cu surface,

rinsing the Cu-Zn alloy fill in a solvent;

drying the Cu-Zn alloy fill under a gaseous flow;

annealing the Cu-Zn alloy fill formed in the via and on the Cu surface, thereby forming a reduced-oxygen Cu-Zn alloy fill having a uniform zinc distribution;

20 planarizing the reduced-oxygen Cu-Zn alloy fill and the Cu surface, thereby completing formation of a reduced-oxygen Cu-Zn alloy filled dual-inlaid interconnect structure; and

completing formation of the semiconductor device.

12. **(original)** A device, as recited in Claim 11,
wherein the chemical solution is nontoxic and aqueous, and
wherein the chemical solution comprises:

at least one zinc (Zn) ion source for providing a plurality of Zn ions;

5 at least one copper (Cu) ion source for providing a plurality of Cu ions;

at least one complexing agent for complexing the plurality of Cu ions;

at least one pH adjuster;

at least one wetting agent for stabilizing the chemical solution, all being dissolved in a volume of deionized (DI) water.

13. **(original)** A device, as recited in Claim 12,

wherein the at least one zinc (Zn) ion source comprises at least one zinc salt selected from a group consisting essentially of zinc acetate $((\text{CH}_3\text{CO}_2)_2\text{Zn})$, zinc bromide (ZnBr_2) , zinc carbonate hydroxide $(\text{ZnCO}_3 \cdot 2\text{Zn}(\text{OH})_2)$, zinc dichloride (ZnCl_2) ,
 5 zinc citrate $(\text{O}_2\text{CCH}_2\text{C}(\text{OH})(\text{CO}_2)\text{CH}_2\text{CO}_2)_2\text{Zn}_3$, zinc iodide (ZnI_2) , zinc L-lactate $((\text{CH}_3\text{CH}(\text{OH})\text{CO}_2)_2\text{Zn})$, zinc nitrate $(\text{Zn}(\text{NO}_3)_2)$, zinc stearate $((\text{CH}_3(\text{CH}_2)_{16}\text{CO}_2)_2\text{Zn})$, zinc sulfate (ZnSO_4) , zinc sulfide (ZnS) , zinc sulfite (ZnSO_3) , and their hydrates.

14. **(original)** A device, as recited in Claim 12,

wherein the at least one copper (Cu) ion source comprises at least one copper salt selected from a group consisting essentially of copper(I) acetate $(\text{CH}_3\text{CO}_2\text{Cu})$, copper(II) acetate $((\text{CH}_3\text{CO}_2)_2\text{Cu})$, copper(I) bromide (CuBr) , copper(II) bromide (CuBr_2) , copper(II) hydroxide $(\text{Cu}(\text{OH})_2)$, copper(II) hydroxide phosphate $(\text{Cu}_2(\text{OH})\text{PO}_4)$, copper(I) iodide (CuI) , copper(II) nitrate hydrate $((\text{CuNO}_3)_2)$, copper(II) sulfate (CuSO_4) , copper(I) sulfide (Cu_2S) , copper(II) sulfide (CuS) , copper(II) tartrate $((\text{CH}(\text{OH})\text{CO}_2)_2\text{Cu})$, and their hydrates.

15. **(canceled)**

16. **(currently amended)** A device, as recited in Claim ~~11~~5,

~~wherein the cathode-wafer comprises the Cu surface, and~~

wherein the anode comprises at least one material selected from a group consisting essentially of copper (Cu), a copper-platinum alloy (Cu-Pt), titanium (Ti), platinum (Pt), a titanium-platinum alloy (Ti-Pt), an anodized copper-zinc alloy (Cu-Zn, i.e., brass), a platinized titanium (Pt/Ti), and a platinized copper-zinc (Pt/Cu-Zn, i.e., platinized brass).

17. **(original)** A device, as recited in Claim 11,
wherein said semiconductor substrate further comprises a barrier layer formed in the via
under said Cu surface, and
wherein the barrier layer comprises at least one material selected from a group consisting
essentially of titanium silicon nitride ($\text{Ti}_x\text{Si}_y\text{N}_z$), tantalum nitride (TaN), and
tungsten nitride (W_xN_y).
18. **(original)** A device, as recited in Claim 17,
wherein said semiconductor substrate further comprises an underlayer formed on the
barrier layer,
wherein said underlayer comprises at least one material selected from a group consisting
essentially of tin (Sn) and palladium (Pd), and
wherein said Cu surface is formed over said barrier layer and on said underlayer.
19. **(original)** A device, as recited in Claim 18,
wherein said underlayer comprises a thickness range of approximately 15 Å to
approximately 50 Å,
wherein said barrier layer comprises a thickness range of approximately 30 Å to
approximately 50 Å,
wherein said Cu surface comprises a thickness range of approximately 50 Å to
approximately 70 Å, and
wherein said Cu-Zn alloy fill comprises a thickness range of approximately 300 Å to
approximately 700 Å.
20. **(original)** A semiconductor device, having a first interim reduced-oxygen copper-zinc
(Cu-Zn) alloy fill formed on a copper (Cu) surface and a second interim reduced-oxygen
Cu-Zn alloy fill formed on a Cu-fill, both films being formed by electroplating the Cu
surface and the Cu-fill, respectively, in a chemical solution, comprising:
a semiconductor substrate having a via; and
an encapsulated dual-inlaid interconnect structure formed and disposed in said via, said
interconnect structure comprising:
at least one Cu surface formed in said via;

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a first interim reduced-oxygen Cu-Zn alloy fill formed and disposed on the at least one Cu surface;
a Cu-fill formed and disposed on said interim reduced-oxygen Cu-Zn alloy fill;
and
a second interim reduced-oxygen Cu-Zn alloy fill formed and disposed on the Cu-fill.